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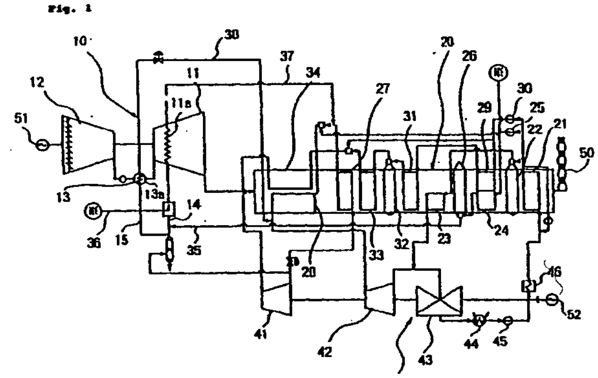
(54) COMBINED CYCLE POWER GENERATING PLANT AND METHOD OF SUPPLYING COOLING STEAM FOR GAS TURBINE IN SAME

(57) In combined cycle power plant comprising combination of gas turbine plant and steam turbine plant, gas turbine cooling steam temperature is adjusted appropriately so that gas turbine can be made of easily obtainable material.

Steam supplied from intermediate pressure evaporator is mixed into cooling steam supply passage for supplying therethrough exhaust steam from high pressure steam turbine into gas turbine high temperature portion as cooling steam, thereby cooling steam temperature is lowered without lowering of entire efficiency and material of less heat resistant ability becomes usable as material forming the gas turbine high temperature portion to be cooled so that design and manufacture of the gas turbine may be satisfied by less expensive and easily obtainable material.

Fig. 1



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Description

BACKGROUND OF THE INVENTION:

Field of the Invention:

[0001] The present invention relates to a combined cycle power plant in which a gas turbine plant and a steam turbine plant are combined and a cooling steam supply method for a gas turbine in operation thereof.

Description of the Prior Art:

[0002] A combined cycle power plant is a power system in which a gas turbine plant and a steam turbine plant are combined, wherein a gas turbine takes charge of a high temperature section of thermal energy and a steam turbine takes charge of a low temperature section thereof, so that the thermal energy is recovered for an effective use thereof and this power system is now being paid a high attention to.

[0003] In the combined cycle power plant, research and development are being carried out aiming at a higher temperature gas turbine as one means for enhancing the efficiency.

[0004] On the other hand, in order to attain such a higher temperature, improvement of cooling system which takes account of heat resisting ability of turbine structural elements must be pursued and as the result of various tries and errors, a steam cooled system which uses steam as cooling medium, instead of a prior art using compressed air, is in progress now.

[0005] One example thereof is the Japanese laid-open patent application No. Hei 05(1993)-163960, wherein a cooling steam is obtained from intermediate pressure steam of a waste heat recovery boiler but there is obtainable no sufficient volume of the steam resulting in difficulty to effect a stable and secure cooling.

[0006] Thus, as a further progress thereafter, putting eyes on a sufficient volume and a stable cooling, a cooling system using exhaust steam from a high pressure steam turbine as the cooling steam is now being developed.

[0007] In the prior art steam cooled system as mentioned above, progress has been done from the system using intermediate pressure steam as the cooling medium to that using high pressure exhaust steam with result that the practicality has been enhanced further, but the high pressure exhaust steam is of a high temperature at same time, hence a gas turbine high temperature portion which is a portion to be cooled must be made of a selected material which can resist such a high temperature.

[0008] A high temperature resistible material, being required to be of properties necessary for that material, becomes very expensive and in case of a turbine disc among others, for example, there is a large difficulty in obtaining an appropriate material therefor within limited conditions of price and the like and this leads to a serious problem in the design and manufacture of the plant.

SUMMARY OF THE INVENTION:

[0009] In view of the problem in the prior art, it is an object of the present invention to provide a combined cycle power plant and a cooling steam supply method for a gas turbine thereof wherein cooling steam used as cooling medium is appropriately adjusted of its temperature with a functional stability of steam cooled system being by no means damaged, so that the gas turbine can be made of an easily obtainable material.

[0010] In order to attain said object, a first invention hereof provides;

> a combined cycle power plant comprising combination of a gas turbine plant, a waste heat recovery boiler and a steam turbine plant;
> said gas turbine plant being constructed of a gas turbine, an air compressor driven by said gas turbine and a combustor for burning fuel together with compressed air supplied from said air compressor;
> said waste heat recovery boiler being for generating steam by exhaust heat of said gas turbine as heat source and being constructed of portions, mutually connected by pipings, of a high pressure steam generating portion, an intermediate pressure steam generating portion and a low pressure steam generating portion; said high pressure steam generating portion comprising a high pressure economizer, a high pressure feed water pump, a high pressure evaporator and a high pressure superheater; said intermediate pressure steam generating portion comprising an intermediate pressure economizer, an intermediate pressure feed water pump, an intermediate pressure evaporator and an intermediate pressure reheater; and said low pressure steam generating portion comprising a low pressure economizer, a low pressure feed water pump, a low pressure evaporator and a low pressure superheater; and
> said steam turbine plant being constructed of steam turbines, mutually connected by pipings, of a high pressure turbine, an intermediate pressure turbine and a low pressure turbine; said high pressure turbine being supplied with high pressure steam from said high pressure steam generating portion; said intermediate pressure turbine being supplied with intermediate pressure steam from said intermediate pressure steam generating portion; and said low pressure turbine being supplied with low pressure steam from said low pressure steam generating portion;
> characterized in that steam supplied from said intermediate pressure evaporator is mixed into a cooling steam supply passage for supplying therethrough exhaust steam from said high pressure tur-

bine as cooling steam into a high temperature portion to be cooled of said gas turbine.

[0011] That is, in the first invention, the exhaust steam from the high pressure turbine is first selected as the cooling medium of the gas turbine high temperature portion. Then, the intermediate pressure steam supplied from the intermediate pressure evaporator of the waste heat recovery boiler is mixed into the exhaust steam from the high pressure turbine, so that the cooling medium of lowered temperature is made up and is supplied into the gas turbine high temperature portion for cooling thereof.

[0012] Thus, the high pressure exhaust steam, which is sufficient in volume, is mixed with the intermediate pressure steam, which is of a lower temperature but has a pressure nearly equal to that of the high pressure exhaust steam, so that the high pressure exhaust steam is lowered of temperature and the high temperature portion to be cooled of the gas turbine can be made of a material of less heat resistant ability and a stable cooling can be effected without lowering of the entire efficiency.

[0013] A second invention hereof provides;

a combined cycle power plant comprising combination of a gas turbine plant, a waste heat recovery boiler and a steam turbine plant;
said gas turbine plant being constructed of a gas turbine, an air compressor driven by said gas turbine and a combustor for burning fuel together with compressed air supplied from said air compressor;
said waste heat recovery boiler being for generating steam by exhaust heat of said gas turbine as heat source and being constructed of portions, mutually connected by pipings, of a high pressure steam generating portion, an intermediate pressure steam generating portion and a low pressure steam generating portion; said high pressure steam generating portion comprising a high pressure economizer, a high pressure feed water pump, a high pressure evaporator and a high pressure superheater; said intermediate pressure steam generating portion comprising an intermediate pressure economizer, an intermediate pressure feed water pump, an intermediate pressure evaporator and an intermediate pressure reheater; and said low pressure steam generating portion comprising a low pressure economizer, a low pressure feed water pump, a low pressure evaporator and a low pressure superheater; and
said steam turbine plant being constructed of steam turbines, mutually connected by pipings, of a high pressure turbine, an intermediate pressure turbine and a low pressure turbine; said high pressure turbine being supplied with high pressure steam from said high pressure steam generating portion; said intermediate pressure turbine being supplied with intermediate pressure steam from said intermediate pressure steam generating portion; and said low pressure turbine being supplied with low pressure steam from said low pressure steam generating portion;
characterized in that a passage to be cooled by fuel of said gas turbine is provided to a cooling steam supply passage for supplying therethrough exhaust steam from said high pressure turbine as cooling steam into a high temperature portion to be cooled of said gas turbine.

[0014] That is, in the second invention, the exhaust steam from the high pressure turbine is first selected as the cooling medium of the gas turbine high temperature portion. Then, said exhaust steam is not directly used as the cooling steam as it is to be supplied into the gas turbine high temperature portion but is heat-exchanged with the gas turbine fuel to be lowered of temperature and then supplied into the gas turbine high temperature portion for cooling thereof.

[0015] There is available as the cooling steam a sufficient amount of the exhaust steam of the high pressure turbine, but this exhaust steam is of a high temperature at same time, hence it is heat-exchanged with the gas turbine fuel to be lowered of temperature, thereby the gas turbine high temperature portion to be cooled can be made of a material which is of a less heat resistant ability and yet a stable cooling can be effected without the entire efficiency being lowered.

[0016] A third invention hereof provides;

a combined cycle power plant comprising combination of a gas turbine plant, a waste heat recovery boiler and a steam turbine plant;
said gas turbine plant being constructed of a gas turbine, an air compressor driven by said gas turbine and a combustor for burning fuel together with compressed air supplied from said air compressor;
said waste heat recovery boiler being for generating steam by exhaust heat of said gas turbine as heat source and being constructed of portions, mutually connected by pipings, of a high pressure steam generating portion, an intermediate pressure steam generating portion and a low pressure steam generating portion; said high pressure steam generating portion comprising a high pressure economizer, a high pressure feed water pump, a high pressure evaporator and a high pressure superheater; said intermediate pressure steam generating portion comprising an intermediate pressure economizer, an intermediate pressure feed water pump, an intermediate pressure evaporator and an intermediate pressure reheater; and said low pressure steam generating portion comprising a low pressure economizer, a low pressure feed water pump, a low pressure evaporator and a low pressure superheater; and

said steam turbine plant being constructed of steam turbines, mutually connected by pipings, of a high pressure turbine, an intermediate pressure turbine and a low pressure turbine; said high pressure turbine being supplied with high pressure steam from said high pressure steam generating portion; said intermediate pressure turbine being supplied with intermediate pressure steam from said intermediate pressure steam generating portion; and said low pressure turbine being supplied with low pressure steam from said low pressure steam generating portion;

characterized in that a reheater is provided as a means for reheating steam which has cooled a high temperature portion to be cooled of said gas turbine.

[0017] That is, in the third invention, the construction is such that the steam which has cooled the gas turbine high temperature portion can be led into the reheater so as to be reheated there, thereby even if the cooling steam after used for cooling of the gas turbine is not high enough for a predetermined temperature for reason that the gas turbine is not of a high temperature enough or the cooling has not been effected sufficiently or the like, then the cooling steam is reheated by the reheater and a necessary heat for the downstream steam turbines such as the intermediate steam turbine can be secured resulting in enhancement of the thermal efficiency.

[0018] A fourth invention hereof provides;

a combined cycle power plant comprising combination of a gas turbine plant, a waste heat recovery boiler and a steam turbine plant;

said gas turbine plant being constructed of a gas turbine, an air compressor driven by said gas turbine and a combustor for burning fuel together with compressed air supplied from said air compressor;

said waste heat recovery boiler being for generating steam by exhaust heat of said gas turbine as heat source and being constructed of portions, mutually connected by pipings, of a high pressure steam generating portion, an intermediate pressure steam generating portion and a low pressure steam generating portion; said high pressure steam generating portion comprising a high pressure economizer, a high pressure feed water pump, a high pressure evaporator and a high pressure superheater; said intermediate pressure steam generating portion comprising an intermediate pressure economizer, an intermediate pressure feed water pump, an intermediate pressure evaporator and an intermediate pressure reheater; and said low pressure steam generating portion comprising a low pressure economizer, a low pressure feed water pump, a low pressure evaporator and a low pressure superheater; and

said steam turbine plant being constructed of steam turbines, mutually connected by pipings, of a high pressure turbine, an intermediate pressure turbine and a low pressure turbine; said high pressure turbine being supplied with high pressure steam from said high pressure steam generating portion; said intermediate pressure turbine being supplied with intermediate pressure steam from said intermediate pressure steam generating portion; and said low pressure turbine being supplied with low pressure steam from said low pressure steam generating portion;

characterized in that a high pressure turbine bypass passage is provided for connecting a superheated steam supply passage for supplying therethrough superheated steam from said high pressure superheater into said high pressure turbine and a cooling steams supply passage for supplying therethrough exhaust steam from said high pressure turbine as cooling steam into a high temperature portion to be cooled of said gas turbine.

[0019] That is, according to the fourth invention, when the plant is to be started in accordance with operation procedures such as in WSS where the plant stops once a week, in DSS where the plant stop once a day or the like, the gas turbine is warmed up in advance by use of the auxiliary boiler or its own compressed air and the initial steam generated by the own boiler is supplied into the cooling steam passage of the gas turbine via the high pressure turbine by-pass passage, so that the warming-up is assisted to be accelerated.

[0020] And when the own boiler steam gets out of initial steam stage to start to be generated stably, the high pressure turbine by-pass passage is closed and the high pressure superheated steam is led into the high pressure turbine and the situation is changed gradually so that the cooling of the gas turbine is done by the high pressure exhaust steam from the high pressure turbine, thereby there is caused no thermal shock etc. and the cooling of the gas turbine can be done stably.

[0021] A fifth invention hereof provides;

a cooling steam supply method in the combined cycle power plant as mentioned in the first invention, characterized in that said gas turbine is supplied with the cooling steam as the combined cycle power plant is operated such that when inlet temperature of said high pressure turbine is set to approximately 566°C, inlet pressure of said high pressure turbine is adjusted to 165 to 175 ata and exhaust steam of said high pressure turbine is maintained to temperature of 330 to 250°C and pressure of 35 to 30 ata.

[0022] That is, in the fifth invention, the inlet pressure of the high pressure turbine is adjusted to 165 to 175 ata, thereby the high pressure exhaust steam property

is lowered to 330 to 250°C and 35 to 30 ata at the outlet of the high pressure turbine, thus the cooling steam can be lowered of the temperature without the efficiency of the downstream equipments, the intermediate pressure turbine for example, being lowered and the downstream gas turbine high temperature portion to be cooled can be made of a material of less heat resistant ability and less expensive and yet a stable cooling can be effected without the entire efficiency being lowered.

[0023] A sixth invention hereof provides;

> a cooling steam supply method in the combined cycle power plant as mentioned in any one of the first to fourth inventions, characterized in that;
> the high temperature portion to be cooled of said gas turbine is supplied into with auxiliary steam prior to start of said gas turbine so that said gas turbine is warmed up; said auxiliary steam being of pressure of combustion gas pressure or more of starting time of said gas turbine;
> said gas turbine is then started in that state to do a holding operation for a predetermined time at a predetermined load;
> when steam from said waste heat recovery boiler comes to a condition of said auxiliary steam, supply of said auxiliary steam is stopped and steam coming, by-passing said high pressure turbine, from the high pressure superheater of said waste heat recovery boiler is supplied into the high temperature portion to be cooled of said gas turbine; and
> when output of said waste heat recovery boiler comes to a rating thereof, said by-passing is closed and exhaust steam from said high pressure turbine is supplied into the high temperature portion to be cooled of said gas turbine so as to switch to a rated operation.

[0024] That is, in the sixth invention, when the plant is to be started in accordance with operational procedures such as in WSS where the plant stops once a week, in DSS where the plant stops once a day or the like, the cooling steam is supplied into the gas turbine portion to be cooled in the following procedures.

[0025] Firstly, the auxiliary steam of a pressure which is not less than that of the combustion gas effective at the starting time of the gas turbine is supplied into the gas turbine in advance of the starting thereof so that the gas turbine is warmed up. Then, the gas turbine is started to do a holding operation for a predetermined time at a predetermined load. The steam temperature and steam pressure of the waste heat recovery boiler are increased gradually, and when the steam condition of the waste heat recovery boiler comes to the steam condition of the auxiliary steam which has been used for the warming-up, supply of the auxiliary steam is stopped and the high pressure superheated steam which by-passes the high pressure turbine is supplied into the gas turbine, and further when the output, or the steam condition, of the waste heat recovery boiler comes to a rating, said by-passing is closed so that the high pressure superheated steam is supplied into the high pressure turbine and the exhaust steam from the high pressure turbine is supplied into the gas turbine, thus the rated operation takes place.

[0026] A seventh invention hereof provides;

> a cooling steam supply method in the combined cycle power plant as mentioned in any one of the first to fourth inventions, characterized in that;
> while the high temperature portion to be cooled of said gas turbine is closed upstream and downstream thereof, said gas turbine is started to do a holding operation for a predetermined time at a low load of level which needs no cooling of the high temperature portion to be cooled of said gas turbine;
> when said waste heat recovery boiler comes to a level to generate a predetermined own boiler steam, said closing is opened and steam coming, by-passing said high pressure turbine, from the high pressure superheater of said waste heat recovery boiler is supplied into the high temperature portion to be cooled of said gas turbine; and
> when output of said waste heat recovery boiler comes to a rating thereof, said by-passing is closed and exhaust steam from said high pressure turbine is supplied into the high temperature portion to be cooled of said gas turbine so as to switch to a rated operation.

[0027] That is, in the seventh invention, when the plant is to be started in accordance with operational procedures such as in WSS where the plant stops once a week, in DSS where the plant stops once a day or the like, the gas turbine portion to be cooled is first closed, by stop valves etc. for example, upstream and downstream thereof and the gas turbine is started. The gas turbine is held in the low load of approximately 20% load from no load which needs no cooling of the gas turbine portion to be cooled and when the own boiler steam of the waste heat recovery boiler starts to be generated to reach a predetermined state of approximately 20 ata, for example, then said stop valves etc. are opened and the high pressure superheated steam, which by-passes the high pressure turbine, is supplied into the gas turbine portion to be cooled. When the gas turbine is further speeded up and the steam from the waste heat recovery boiler comes to a high temperature to reach what is called a rated state of 40 ata, for example, then said by-passing is closed and the high pressure exhaust steam from the high pressure turbine is supplied into the gas turbine portion to be cooled, thus the rated operation takes place.

[0028] An eighth invention hereof provides;

> a combined cycle power plant as mentioned in any

one of the first to fourth inventions, characterized in that a dust collecting filter is provided at a cooling steam inlet portion of the high temperatur portion to be cooled of said gas turbine and a mesh of said dust collecting filter is in a range of 100 to 1000 μm.

[0029] That is, in the eighth invention, the gas turbine is a recovery type steam cooled one, wherein there are provided cooling passages in the combustor, stationary blades and moving blades which are the high temperature portion of the gas turbine and the exhaust steam from the steam turbine is led into said cooling passages as the cooling steam. The dust collecting filter is provided at the cooling steam inlet portion of the gas turbine high temperature portion and the mesh thereof is in the range of 100 to 1000 μm. If the mesh is smaller than that, fine particles contained in the steam are caught and clogging of the mesh is accelerated so as to make a long hour use thereof impossible and need frequent changes of the mesh. As the cooling steam temperature is usually a high temperature of 250°C or more, there is a difficulty in the exchange work of the mesh. But if the mesh is in the range of 100 to 1000 μm, fine particles pass therethrough and these particles scarcely stay in the cooling steam passage with little possibility of accumulation therein because the cooling steam flows therein at a high velocity. Also, there is a case where solids of dropped scales such as iron oxide etc. in the main steam piping system flow into the cooling steam passage with a fear of blockage thereof, but the mesh is in the range of 100 to 1000 μm and the solids, being larger than the mesh usually, can be removed by the mesh mostly.

[0030] As mentioned above, according to the dust collecting filter, fine particles contained in the steam pass through the mesh and comparatively large solid particles only can be removed by the mesh, thereby a long hour use of the mesh becomes possible and frequent exchange work of the mesh due to clogging becomes lessened.

[0031] Further, the dust collecting filter is provided in the cooling steam passage at the inlet portion of the gas turbine high temperature portion with a simple structure of the mesh portion being detachable, thereby no large dust collecting device is needed and the system construction can be simplified.

[0032] A ninth invention hereof provides;

a combined cycle power plant as mentioned in any one of the first to fourth inventions, characterized in that there are provided an impurity removing device which is exclusive for treating water for temperature adjustment, an economizer which is exclusive for heating the water from said impurity removing device and a spray nozzle for spraying the water heated at said economizer into cooling steam which flows into the high temperature portion to be cooled of said gas turbine, so that said cooling steam is adjusted of its temperature.

[0033] That is, in the ninth invention, the gas turbine is a recovery type steam cooled one, wherein the cooling steam is fed from the steam turbine system into the gas turbine high temperature portion for cooling thereof and this cooling steam is returned to the steam turbine system for recovery. But there is sometimes a case where the temperature of the cooling steam is not appropriate for cooling of the gas turbine high temperature portion. As the gas turbine high temperature portion, there are stationary blades and moving blades, for example. The steam temperature which is appropriate for cooling of the stationary blades is higher than that appropriate for cooling of the moving blades, hence if the cooling steam is of an appropriate temperature for cooling of the stationary blades, the cooling steam is needed to be lowered of the temperature and in this case, the temperature is adjusted by water being sprayed into the steam. In such case where the water is so sprayed, there are contained in the water impurities which need to be removed and if the entire amount of the water which has been condensed is to be treated, then the facilities therefor becomes large and the cost therefor also increases.

[0034] Thus, in the present invention, there are provided the exclusive impurity removing device which has a capacity only to treat the water amount necessary for adjusting the cooling steam temperature and the exclusive economizer for heating only the water so treated at the impurity removing device. As the cooling steam is of a high temperature in the range of 250 to 600°C, the water is heated at the economizer so that the temperature of that water is approached as near as possible to the cooling steam temperature. The high temperature water so heated at the economizer is sprayed into the cooling steam for adjustment of the temperature thereof.

[0035] According to the present invention, there are provided only the exclusive impurity removing device of the capacity only to treat the water of the amount necessary for adjusting the cooling steam temperature and the exclusive economizer for heating only the water so treated at the impurity removing device, thereby the cooling steam temperature adjusting system can be compact-sized with no large facilities being needed, the feed water is heated to become the high temperature water of a temperature near the cooling steam temperature and the adjustment of the cooling steam temperature can be done efficiently.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0036]

Fig. 1 is a diagrammatic view showing a combined cycle power plant of a first embodiment according to the present invention.

Fig. 2 is a diagrammatic view showing a combined cycle power plant of a second embodiment according to the present invention.

Fig. 3 is a diagrammatic view showing a combined cycle power plant of third and fifth embodiments according to the present invention.

Fig. 4 is a diagrammatic view showing a combined cycle power plant of a fourth embodiment according to the present invention.

Fig. 5 is a diagrammatic view showing a combined cycle power plant of a sixth embodiment according to the present invention.

Fig. 6 is a diagrammatic view showing a combined cycle power plant of a seventh embodiment according to the present invention.

Fig. 7 is a diagrammatic view showing a combined cycle power plant of an eighth embodiment according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

[0037] A first embodiment according to the present invention will be described with reference to Fig. 1. All the embodiments according to the present invention are made on the basis of a combined cycle power plant consisting basically of three portions of a gas turbine, a steam turbine and a waste heat recovery boiler and the whole aspect of this combined cycle power plant will be described first.

[0038] In Fig. 1, numeral 10 designates a gas turbine plant, which comprises as main equipments a gas turbine 11, an air compressor 12 driven by the gas turbine 11, and a combustor 13 for burning a fuel together with a compressed air supplied from the air compressor 12.

[0039] There are provided within the gas turbine 11 moving blades, stationary blades and the like (not shown), which correspond to a high temperature portion 11a which requires a cooling thereof. The combustor 13 comprises therein a tail tube cooled portion 13a which extends from a combustion chamber rear portion to a combustion gas outlet, and this tail tube cooled portion 13a is also a portion requiring a cooling thereof, like said high temperature portion 11a.

[0040] Also provided are a cooling steam supply passage 14 for supplying therethrough a cooling steam to the high temperature portion 11a of the gas turbine 11 and a cooling steam bifurcation passage 15, bifurcated from the cooling steam supply passage 14, for supplying therethrough the cooling steam to the tail tube cooled portion 13a of the combustor 13.

[0041] Numeral 20 designates a waste heat recovery boiler, which uses an exhaust gas of the gas turbine 11 as a heat source and comprises therein portions of a low pressure steam generating portion, an intermediate pressure steam generating portion and a high pressure steam generating portion.

[0042] If equipments included in said respective steam generating portions are shown approximately in the order of steam flow therein, then the low pressure steam generating portion is composed of a low pressure economizer 21, a low pressure evaporator 22, a low pressure superheater 23, etc. and the intermediate pressure steam generating portion is composed of an intermediate pressure economizer 24, an intermediate pressure feed water pump 25, an intermediate pressure evaporator 26, an intermediate pressure first reheater 27, an intermediate pressure second reheater 28. etc.

[0043] Also, the high pressure steam generating portion is composed of a high pressure first economizer 29, a high pressure feed water pump 30, a high pressure second economizer 31, a high pressure evaporator 32, a high pressure first superheater 33, a high pressure second superheater 34, etc.

[0044] Numeral 40 designates a steam turbine plant, which comprises a high pressure turbine 41 supplied with a high pressure steam from the high pressure second superheater 34 of the waste heat recovery boiler 20, an intermediate pressure turbine 42 supplied with an intermediate pressure steam from the intermediate pressure second reheater 28 and a low pressure turbine 43 supplied with an exhaust steam from the intermediate pressure turbine 42 and a low pressure steam from the low pressure superheater 23.

[0045] It is to be noted that the construction is made such that an exhaust steam from the low pressure turbine 43 is condensed into water at a condenser 44 provided downstream thereof and this water is circulated to the waste heat recovery boiler 20 via a boiler feed water pump 45 and a gland steam condenser 46 sequentially. Numeral 50 designates a stack, numeral 51 designates a generator driven by the gas turbine plant 10 and numeral 52 designates a generator driven by the steam turbine plant 40.

[0046] While various equipments are named and described schematically, the present embodiment relates to a combined cycle power plant consisting of said gas turbine plant 10, said waste heat recovery boiler 20 and said steam turbine plant 40 and includes further the following construction.

[0047] That is, an intermediate pressure steam supply passage 35 connects at its one end to the intermediate pressure evaporator 26 of the waste heat recovery boiler 20 so as to take out an intermediate pressure steam therefrom and this intermediate pressure steam supply passage 35 connects at its the other end to the cooling steam supply passage 14 at a position downstream of a bifurcation position of the cooling steam supply passage 14 and the cooling steam bifurcation passage 15 so as to make the intermediate pressure steam mixed into the cooling steam supply passage 14.

[0048] Also, a back-up spray water supply passage 36 connects at its one end to the cooling steam supply passage 14 at a position further downstream of a connection position of the cooling steam supply passage 14 and the intermediate pressure steam supply passage

35 and at its the other end to the intermediate pressure feed water pump 25 upstream thereof.

[0049] Numeral 37 designates a gas turbine cooling steam recovery passage, which connects to an inlet side of the intermediate pressure second reheater 28 and numeral 38 designates a tail tube cooling steam recovery passage, which connects to an outlet side of the intermediate pressure second reheater 28.

[0050] In the present embodiment constructed as above, cooling of the high temperature portion 11a of the gas turbine 11 and the tail tube cooled portion 13a of the combustor 13, while in a steady operation, is done as follows.

[0051] That is, a high pressure exhaust steam from the high pressure turbine 41 is supplied into the cooling steam supply passage 14 to be bifurcated on the way, wherein one portion thereof flows to the combustor 13 via the cooling steam bifurcation passage 15 for cooling the tail tube cooled portion 13a and the other flows to the gas turbine 11 via the cooling steam supply passage 14 for cooling the high temperature portion 11a thereof.

[0052] At this time, the cooling steam flowing to the gas turbine 11 via the cooling steam supply passage 14 is mixed with the intermediate pressure steam supplied from the intermediate pressure evaporator 26 via the intermediate pressure steam supply passage 35, so that temperature of the cooling steam in the cooling steam supply passage 14 is lowered.

[0053] If one example of such temperature lowering is to be shown, the temperature of the high pressure exhaust steam coming out of the high pressure turbine 41 is approximately 370°C and if a turbine portion, especially a movable portion such as a moving blade and a disc, is exposed to the steam of that temperature, it will be put in a severe heat resisting condition and an expensive material will be needed for overcoming same, which results in aggravation of the economical conditions.

[0054] But the intermediate pressure steam coming from the intermediate pressure evaporator 26 is of a temperature of approximately 250°C and if this intermediate pressure steam is mixed into said high pressure exhaust steam of approximately 370°C, then the temperature of this mixed steam lowers to approximately 330°C and the material of said turbine movable portion such as the moving blade and the disc can be satisfied by a less expensive and easily obtainable material, which results in a favorable turn in the economical conditions.

[0055] The intermediate pressure steam supplied from the intermediate pressure evaporator 26 to be mixed into the high pressure exhaust steam is approximately same in the pressure as the high pressure exhaust steam coming out of the high pressure turbine 41, hence there occurs no lowering of the entire efficiency due to such mixing and a predetermined temperature lowering can be effected.

[0056] The tail tube cooled portion 13a of the combustor 13, being a fixed structural element, is resistible with a less expensive material even to th temperature condition of same 370°C, hence the intermediate pressure steam may not be mixed into the cooling steam bifurcation passage 15 actively, unless needed specifically.

[0057] Also, as a back-up measure for the case where the intermediate pressure steam cannot be obtained as expected, a hot water supplied from the intermediate pressure feed water pump 25 via the back-up spray water supply passage 36 is sprayed into the cooling steam supply passage 14 so that the temperature of the cooling steam in the cooling steam supply passage 14 is lowered securely.

[0058] The cooling steam which has cooled the high temperature portion 11a of the gas turbine 11 is recovered into the intermediate pressure second reheater 28 via the gas turbine cooling steam recovery passage 37, and the cooling steam which has cooled the tail tube cooled portion 13a of the combustor 13 comes to the outlet side of the intermediate pressure second reheater 28 via the tail tube cooling steam recovery passage 38 to join with another steam which has been heated through the intermediate pressure second reheater 28 to be further supplied to the intermediate pressure turbine 42 for recovery.

[0059] According to the present embodiment constructed as mentioned above, the cooling steam for cooling the high temperature portion 11a of the gas turbine 11 is obtained by the high pressure exhaust steam from the high pressure turbine 41 being mixed with the intermediate pressure steam from the intermediate pressure evaporator 26 to be lowered of temperature, thereby the high temperature portion 11a of the gas turbine 11 is required less severely to be heat resistant and a manufacturing cost of the turbine can be saved greatly.

[0060] Next, a second embodiment according to the present invention will be described with reference to Fig. 2. It is to be noted that same components or parts as those in the mentioned first embodiment are given same reference numerals in the figure with repeated description being omitted as much as possible and a featured construction of the present embodiment will be described mainly.

[0061] In the present embodiment, there is provided a fuel heater 16 in the cooling steam supply passage, 14 for supplying therethrough the high pressure exhaust steam from the high pressure turbine 41 to the gas turbine 11, said fuel heater 16 being positioned upstream of a bifurcation position of the cooling steam supply passage 14 and the cooling steam bifurcation passage 15 for supplying therethrough the cooling steam to the combustor 13, so that a heat exchange may be done between a fuel to be supplied into the combustor 13 and the high pressure exhaust steam from the high pressure turbine 41.

[0062] That is, the high pressure exhaust steam supplied from the high pressure turbine 41 via the cooling

steam supply passage 14 is first cooled at the fuel heater 16 by the fuel to be supplied into the combustor 13 to be then bifurcated, wherein one portion thereof flows to the combustor 13 via the cooling steam bifurcation passage 15 for cooling the tail tube cooled portion 13a and the other flows to the gas turbine 11 via the cooling steam supply passage 14 for cooling the high temperature portion 11a thereof.

[0063] If one example of a temperature lowering of the high pressure exhaust steam cooled at the fuel heater 16 is to be shown, supposing that the temperature of the high pressure exhaust steam coming out of the high pressure turbine 41 is approximately 375°C, then a turbine portion, especially a movable portion such as a moving blade and a disc, is exposed to the steam of that temperature to be put in a severe heat resisting condition and an expensive material will be needed for overcoming same, which results in aggravation of the economical conditions.

[0064] But the temperature of the fuel of gas turbine coming into the fuel heater 16 is as low as 300°C or less and if the high pressure exhaust steam is cooled by that fuel, then the temperature of the high pressure exhaust steam is lowered to approximately 330°C and the material of said turbine movable portion such as the moving blade and the disc can be satisfied by a less expensive and easily obtainable material, which results in a favorable turn in the economical conditions.

[0065] According to the present embodiment constructed as mentioned above, the cooling steam for cooling the high temperature portion 11a of the gas turbine 11 and the tail tube cooled portion 13a of the combustor 13 is obtained by the high pressure exhaust steam from the high pressure turbine 41 being cooled by the gas turbine fuel to be lowered of temperature, thereby said high temperature portions 11a, 13a are required less severely to be heat resistant so that employment of an easily obtainable material becomes possible and the manufacturing cost can be saved greatly.

[0066] In the present embodiment also, like in the first embodiment, the cooling steam which has cooled the high temperature portion 11a of the gas turbine 11 is recovered into the intermediate pressure second reheater 28 via the gas turbine cooling steam recovery passage 37.

[0067] That is, because said cooling steam can be reheated by the intermediate pressure second reheater 28, even if the cooling steam after used for the cooling of the gas turbine 11 is of a temperature which is less than a predetermined level for reason that the high temperature portion 11a of the gas turbine 11 is not of a sufficiently high temperature or that the cooling thereof has not been done sufficiently, that cooling steam can be reheated by said reheater 28, thereby necessary heat for the downstream steam turbines such as the intermediate pressure turbine can be secured and this results in enhancement of the thermal efficiency.

[0068] Next, a third embodiment according to the present invention will be described with reference to Fig. 3. It is to be noted that same components or parts as those in the mentioned first embodiment are given same reference numerals in the figure with repeated description being omitted.

[0069] In Fig. 3, numeral 14a designates a high pressure turbine by-pass passage, which connects at its one end to a superheated steam supply passage 41a for supplying therethrough steam from the waste heat recovery boiler 20 to the high pressure turbine 41 and at its the other end to a position upstream of a bifurcation position of the cooling steam supply passage 14 for supplying therethrough the high pressure exhaust steam from the high pressure turbine 41 to the high temperature portions to be cooled of the gas turbine plant 10 and a high pressure steam exhaust passage 27a for supplying therethrough the high pressure exhaust steam from the high pressure turbine 41 to the intermediate pressure first reheater 27.

[0070] That is, in the combined cycle plant, when the plant is to be started in accordance with operation procedures of WSS (weekly start and stop) or DSS (daily start and stop) or the like, the gas turbine is warmed up in advance by a method using an auxiliary boiler or its own compressed air or the like and an initial steam generated at the own boiler is supplied into the cooling steam passage of the gas turbine via the high pressure turbine by-pass passage 14a, so that the warming-up is assisted to be accelerated.

[0071] And when the own boiler steam starts to be generated stably, said by-pass passage 14a is closed and a high pressure superheated steam is introduced into the high pressure turbine 41 and the cooling of gas turbine is done by the high pressure exhaust steam from the high pressure turbine 41.

[0072] According to the present embodiment constructed as mentioned above, the gas turbine cooling can be done with none of thermal shock etc. being caused.

[0073] Next, a fourth embodiment according to the present invention will be described with reference to Fig. 4. It is to be noted that same components or parts as those in the mentioned first embodiment are given same reference numerals in the figure with repeated description being omitted.

[0074] In the present embodiment, the high pressure exhaust steam from the high pressure turbine 41 is supplied into the cooling steam supply passage 14 to be then bifurcated, wherein one portion thereof flows to the combustor 13 via the cooling steam bifurcation passage 15 for cooling the tail tube cooled portion 13a and the other flows to the gas turbine 11 via the cooling steam supply passage 14 for cooling the high temperature portion 11a thereof.

[0075] The cooling steam is theretofore made up at the high pressure turbine 41 as follows, wherein the high pressure steam supplied into the high pressure tur-

bine 41 is set to pressure of 165 to 175 ata and temperature of appr ximately 566°C by an appropriate control means (not shown).

[0076] Then, the steam supplied into the high pressure turbine 41 in said pressure and temperature changes to pressure of 30 to 35 ata and temperature of 330 to 250°C at an outlet of the high pressure turbine 41. That is, in order to obtain a high pressure steam property of said 30 to 35 ata, 330 to 250°C at the high pressure turbine 41 outlet, taking account of an ordinary turbine expansion, the pressure at an inlet of the high pressure turbine 41 is required to be 165 to 175 ata when the inlet temperature is selected to approximately 566°C which is an ordinary value.

[0077] The cooling steam coming out of the high pressure turbine 41 is supplied to the high temperature portion 11a of the gas turbine 11 and the tail tube cooled portion 13a of the combustor 13 via the cooling steam supply passage 14 and the cooling steam bifurcation passage 15 and the temperature of this cooling steam is made up to 330 to 250°C as mentioned above.

[0078] Because this temperature range is not of a specifically severe requirement as a heat resistant performance of a material composing said high temperature portion 11a and the tail tube cooled portion 13a, hence the material of the turbine movable portion such as the moving blade and the disc can be satisfied by a less expensive and easily obtainable material, which results in a favorable turn in the economical conditions.

[0079] It is to be noted that in the present embodiment, the steam property is specified at the high pressure turbine 41 inlet and the cooling steam of predetermined property is obtained at the high pressure turbine 41 outlet and the heat resisting temperature condition at said high temperature portion 11a and tail tube cooled portion 13a is satisfied without the cooling steam being made up otherwise, but if there occurs an unexpected variation in the steam making up function before the high pressure turbine 41 or in the operation of the high pressure turbine 41 or the like, an intermediate pressure steam can be supplied into the cooling steam supply passage 14 for back-up via the intermediate pressure steam supply passage 35.

[0080] Further, said cooling steam is set to the pressure of 30 to 35 ata at the high pressure turbine 41 outlet and while this pressure range is maintained, there occurs no performance lowering of the downstream intermediate pressure turbine 42, which results in no fear of efficiency lowering of the entire system.

[0081] Also, the steam supplied into the intermediate pressure turbine 42 returns to 566°C by heating at the intermediate pressure second reheater 28, recovery heat at the gas turbine plant 10 and the like, and a low pressure steam at an inlet portion of the low pressure turbine is made up to a pressure of 3 to 6 ata.

[0082] According to the present embodiment as mentioned above, the cooling steam for cooling the high temperature portion 11a of the gas turbine 11 and the tail tube cooled portion 13a of the combustor 13 is made up to a favorable property at the high pressure turbine 41 outlet, thereby there occurs no fear of efficiency lowering of the downstream intermediate pressure turbine and the structural material of the high temperature portion 11a of the gas turbine 11 and the tail tube cooled portion 13a of the combustor 13 is required of a less severe heat resistant ability without a specific equipment being provided otherwise and the turbine manufacturing cost can be saved greatly.

[0083] Next, a fifth embodiment according to the present invention will be described with reference to Fig. 3. It is to be noted that same components or parts as those in the mentioned first embodiment are given same reference numerals in the figure with repeated description being omitted.

[0084] In the gas turbine 11, there are provided the combustor 13 for supplying an operating gas to the gas turbine 11 and the air compressor 12 for supply a compressed air to same. Also provided are the high temperature portion 11a of moving blades and stationary blades of the gas turbine 11 and the tail tube cooled portion 13a along a wall surface of the combustor 13.

[0085] An auxiliary boiler (not shown) is provided outside of the combined cycle system so that steam may be supplied therefrom to the combined cycle system or to other facilities of the power plant in case of necessity.

[0086] A steam turbine portion as a bottoming cycle of the combined cycle is constructed by the high pressure turbine 41, the intermediate pressure turbine 42 and the low pressure turbine 43.

[0087] Steam from the high pressure second superheater 34 of the waste heat-recovery boiler 20 flows, bypassing the high pressure turbine 41, to the high temperature portion 11a of the gas turbine 11 via the high pressure turbine by-pass passage 14a and the cooling steam supply passage 14.

[0088] The cooling steam supply passage 14 also forms a passage for supplying therethrough a high pressure exhaust steam of the high pressure turbine 41 as the cooling steam of the high temperature portion 11a of the gas turbine and the gas turbine cooling steam recovery passage 37 forms a passage for recovering therethrough the thermal energy of the cooling steam which has been elevated of temperature at the high temperature portion 11a into the waste heat recovery boiler 20.

[0089] Downstream of the high pressure turbine 41 and the subsequent intermediate pressure turbine 42 and low pressure turbine 43, the condenser 44 is provided and a high temperature water condensed there is returned to the waste heat recovery boiler 20 to be evaporated again to repeat the same cycle.

[0090] Operational function of the present embodiment formed as mentioned above will be described. That is, in the power plant, there are often taken place plant starts and stops such as in WSS where the plant starts and stops once a week, in DSS where the plant

stops once a day and starts on the next day or after completion of a periodic inspection.

[0091] When th plant is so started, prior to start of the gas turbine 11, auxiliary steam from the auxiliary boiler is supplied into the gas turbine 11 and the combustor 13 so that the high temperature portion 11a of the gas turbine 11 and the tail tube cooled portion 13a along the wall surface of the combustor 13 are warmed up to be finally recovered into the condenser 44 via a passage which is not shown in the figure.

[0092] It is to be noted that the auxiliary steam condition in this case is preferably of a pressure of approximately 20 ata and a temperature of 200 to 300°C, said pressure being higher than that of a combustion gas generated at the starting time of the gas turbine 11 so that equipments may not be damaged by the pressure of the combustion gas generated at said time.

[0093] Then, following said warming up, the gas turbine 11 is started to be gradually speeded up to reach approximately 20% gas turbine load and is then held in this state of load for a predetermined time to be maintained until what is called an own boiler steam is generated by the waste heat recovery boiler 20 which uses an exhaust gas of the gas turbine 11 as a heat source.

[0094] When the own boiler steam generated by the waste heat recovery boiler 20 comes to a steam condition of approximately 20 ata which corresponds to the pressure of the auxiliary steam, supply of the auxiliary steam is stopped and a steam from the high pressure second superheater 34 is supplied to the gas turbine 11 and the combustor 13 via the superheated steam supply passage 41a, the high pressure turbine by-pass passage 14a and then the cooling steam supply passage 14. The cooling steam which has passed through the high temperature portions 11a, 13a of the gas turbine 11 and the combustor 13 is led into the intermediate pressure second reheater 28 via the gas turbine cooling steam recovery passage 37.

[0095] Then, the gas turbine 11 is further speeded up toward the rating and when an outlet pressure of the high pressure second superheater 34 reaches 40 ata, achievement of the rating is confirmed and the high pressure turbine by-pass passage 14a is closed so that the high pressure superheated steam from the high pressure second superheater 34 of the waste heat recovery boiler 20 is supplied into the high pressure turbine 41 via the superheated steam supply passage 41a and the operation is switched to a rated operation.

[0096] Thus, later on from said stage, while the high pressure exhaust steam from the high pressure turbine 41 is supplied to gas turbine cooled portions, that is, the high temperature portions 11a, 13a of the gas turbine 11 and the combustor 13 for cooling thereof via the cooling steam supply passage 14, the cooling steam is heated through cooling of said cooled portions to be given a thermal energy and is led into the intermediate pressure turbine 42 via the gas turbine cooling steam recovery passage 37 and the intermediate pressure second reheater 28 to be recovered of the thermal energy.

[0097] According to the present embodiment, prior to the start of the gas turbine, the cooled portions are filled with the auxiliary steam, a drain etc. therein are removed and the gas turbine cooled portions are warmed by the warm-up operation using the auxiliary steam, thereby even when the rated operation approaches and the own boiler steam from the high pressure second superheater 34 comes in, there occurs no thermal shock, thus a plant having a high reliability and safety can be realized.

[0098] Next, a sixth embodiment according to the present invention will be described with reference to Fig. 5. In Fig. 5, which shows arrangement relationship among three components of a gas turbine, a steam turbine and a waste heat recovery boiler in a combined cycle power plant.

[0099] Numeral 110 designates a gas turbine, which comprises a combustor 111 for supplying an operating gas to the gas turbine 110 and an air compressor 112 for supplying a compressed air to same. Also provided are a high temperature portion 110a consisting mainly of moving blades and a high temperature portion 110b consisting mainly of stationary blades both in the gas turbine 110 and a high temperature portion 111a formed along a wall surface of the combustor 111.

[0100] Numeral 120 designates a high pressure turbine, which, together with an intermediate pressure turbine and a low pressure turbine (not shown), forms a steam turbine portion as a bottoming cycle of the combined cycle. In Fig. 5, the high pressure turbine 120 only is shown representatively.

[0101] Numeral 121 designates a by-pass passage, which forms a passage for supplying therethrough, bypassing the high pressure turbine 120, a steam from a waste heat recovery boiler 130, to be described later, to the high temperature portions 110a, 110b and 111a of the gas turbine 110 and the combustor 111.

[0102] Numeral 122 designates a high pressure exhaust steam passage and numeral 123 designates a recovery passage. The high pressure exhaust steam passage 122 forms a passage for supplying therethrough a high pressure exhaust steam from the high pressure turbine 120 to the high temperature portions 110a, 110b and 111a of the gas turbine 110 and the combustor 111, and the recovery passage 123 forms a passage for recovering therethrough a thermal energy of the cooling steam, which has been elevated of temperature through cooling of the high temperature portions 110a, 110b and 111a, into the waste heat recovery boiler 130.

[0103] The waste heat recovery boiler 130, which is of a three-pressure type of low pressure, intermediate pressure and high pressure generally, is shown here by its high pressure superheater 131 and reheater 131 representatively for easiness of description with other portions thereof being omitted. Numeral 133 designates a

high pressure steam passage, which supplies therethrough a high pressure steam from a high pressure evaporator (HPEV) (not shown) to the high pressure superheater 131. Numeral 134 designates a reheated steam passage, which forms a passage for supplying a steam, which has been made up at the reheater 132, to the intermediate pressure turbine (not shown).

[0104] It is to be noted that the figure here shows only the basic concept using connecting lines and even in case where same one line is used for showing two or more passages, an exhaust steam passage 115 and the recovery passage 123, for example, there are provided stop valves on the way, where needed, and the respective flow directions therein are suitably regulated to meet predetermined operational directions, for example, the exhaust steam passage 115 is directed to the left in the figure to connect to a condenser 125 and the recovery passage 123 is directed to the right in the figure to connect to the waste heat recovery boiler 130.

[0105] Also, in a portion surrounded by A in the figure comprising the gas turbine 110 and the combustor 111, there are provided stop valves upstream and downstream of the high temperature portions 110a, 110b and 111a, respectively, so that the respective passages thereof are openable and closable although not shown in the figure.

[0106] Operational function of the present embodiment formed as mentioned above will be described. That is, in the power plant, there are often taken place plant starts and stops such as in WSS where the plant starts and stops once a week, in DSS where the plant stops once a day and starts on the next day or after completion of a periodic inspection.

[0107] When the plant is so started, the upstream and downstream stop valves of the high temperature portions 110a, 110b and 111a of the gas turbine 110 and the combustor 111 in the portion A are closed and the gas turbine 110 is started.

[0108] The gas turbine 110 is gradually speeded up in said state to reach a low load of approximately 20% load from no load which needs no cooling of the high temperature portions 110a, 110b and 111a and is then held in this state of load to be maintained until the own boiler steam is generated by the waste heat recovery boiler 130.

[0109] When the own boiler steam of the waste heat recovery boiler 130 comes to a steam condition of approximately 20 ata, then said stop valves are opened and a steam from the high pressure superheater 131 is supplied into the high temperature portions 110a, 110b and 111a of the gas turbine 110 and the combustor 111 via the by-pass passage 121 so as to start cooling of the gas turbine 110 and the combustor 111. The cooling steam which has passed through the high temperature portions 110a, 110b and 111a of the gas turbine 110 and the combustor 111 flows to the reheater 132 via the by-pass passage 123.

[0110] Then, the gas turbine 110 is further speeded up toward the rating and when an outlet pressure of the high pressure superheater 131 reaches 40 ata, achievement of the rating is confirmed and the by-pass passage 121 is closed so that the high pressure superheated steam from the high pressure superheater 131 of the waste heat recovery boiler 130 is supplied into the high pressure turbine 120 via a superheated steam passage 124 and the operation is switched to a rated operation. Thus, later on from this stage, while the high pressure exhaust steam from the high pressure turbine 120 is supplied to gas turbine cooled portions, that is, the high temperature portions 110a, 110b and 111a of the gas turbine 110 and the combustor 111 for cooling thereof via the high pressure exhaust steam passage 122, the cooling steam is heated through cooling of said cooled portions to be given a thermal energy and is led into the intermediate pressure turbine (not shown) via the recovery passage 123, the reheater 132 and the reheated steam passage 134 to be recovered of the thermal energy.

[0111] According to the present embodiment, the gas turbine 110 is started with the cooling steam passages of the high temperature portions 110a, 110b and 111a of the gas turbine 110 and the combustor 111 being closed so that no drain etc. is allowed to come in there, and is warmed up while being held in a low load level which needs no cooling of the gas turbine cooled portions. Then, when the own boiler steam generated by the waste heat recovery boiler 130 comes to a predetermined steam condition, cooling of the gas turbine cooled portions is started and the rated operation is effected finally in the rated steam condition. By the operation being done in said procedures, the gas turbine cooled portions are gradually elevated of temperature and then is cooled, hence even when the rated operation approaches and the own boiler steam from the high pressure superheater 131 comes in, there occurs no thermal shock, thus a plant having a high reliability and safety can be realized.

[0112] Next, a seventh embodiment according to the present invention will be described with reference to Fig. 6. It is to be noted that same components or parts as those in the mentioned first embodiment are given same reference numerals in the figure with repeated description being omitted.

[0113] In Fig. 6, numeral 18 designates a dust collecting filter, which is disposed on the way of the cooling steam bifurcation passage 15, that is, near an inlet of the combustor 13. Numeral 19 designates also a dust collecting filter, which is disposed on the way of the cooling steam supply passage 14 for supplying therethrough the exhaust steam as the cooling steam from the high pressure turbine 41 into the high temperature portion 11a of the gas turbine 11.

[0114] These dust collecting filters, although not shown in detail, are constructed with their filter mesh portions being detachable so as to be inserted or drawn out easily. The mesh size is in a range of 100 to 1000

µm. If the mesh size is smaller than said range, fine particles in the steam sticks to the mesh gradually with a long hour use thereof so that frequent exchanges of the mesh becomes necessary, but because the cooling steam is of a high temperature of 250°C or more, exchange work of the mesh is difficult.

[0115] By selecting the range of the mesh as mentioned above, fine particles in the steam pass through the mesh to enter the high temperature portion 11a of the gas turbine 11 and the tail tube cooled portion 13a of the combustor 13. Nevertheless, because the steam flows there at a high velocity, there is little possibility of accumulation of the fine particles in the passages. Further, solid particles of impurities of dropped scales etc in the respective steam passages, being larger than the mesh size usually, are removed by the mesh before they enter the high temperature portion 11a and the tail tube cooled portion 13a; hence blockage of the passages due to these dropped solid particles can be prevented.

[0116] Also, because the mesh size is in the range of 100 to 1000 µm, dropped solid particles from main steam pipings only are removed by the mesh and fine particles pass therethrough, a long hour use thereof becomes possible and frequency of exchanging the mesh due to clogging thereof is reduced remarkably.

[0117] An eighth embodiment according to the present invention will be described with reference to Fig. 7. It is to be noted that same components or parts as those in the mentioned first embodiment are given same reference numerals in the figure with repeated description being omitted.

[0118] In Fig. 7, numeral 60 designates an impurity removing device, which is exclusive for removing fine particles of solid and the like in feed water and is of a capacity corresponding to a feed water spray amount. Numeral 70 designates an economizer, which is exclusive for heating water for feed water spraying only and is of a capacity corresponding to an amount of the feed water. Numeral 71 designates a feed water piping and numeral 72 designates a feed water spray nozzle.

[0119] The cooling steam led into the stationary blades of the high temperature portion 11a of the gas turbine 11, being usually of nearly same temperature as that appropriate for cooling of the stationary blades, can be led into the high temperature portion as it is for cooling of the stationary blades, on the other hand, an appropriate temperature for cooling of the moving blades of the high temperature portion 11a being lower than that for cooling of the stationary blades, the cooling steam led into the high temperature portion 11a for cooling of the moving blades is necessary to be adjusted of the temperature. For this purpose, the temperature adjustment is done such that feed water from the feed water spray nozzle 72 is heated at the economizer 70 so as to approach as near as possible to a steam temperature appropriate for cooling of the moving blades, 318°C for example, and is then sprayed as a high temperature water.

[0120] The feed water is first passed through the exclusive impurity removing device 60 which has a capacity to treat water in the amount corresponding to that of the feed water and is led into the waste heat recovery boiler 20 to be heated to become the high temperature water by the exclusive economizer 70 for heating the feed water and is then led into the feed water piping 71. The high temperature water from the feed water piping 71 is sprayed into cooling steam pipings of the moving blades by the feed water spray nozzle 72 so that the steam flowing through the high temperature portion 11a of the gas turbine 11 is adjusted of temperature appropriately for cooling of the moving blades.

[0121] Said exclusive economizer 70 is made such that an existing economizer in the prior art is separated into a device for heating only the feed water for cooling of the moving blades. Also, the impurity removing device 60 is made exclusively for the feed water sprayed into the steam for cooling of the moving blades so as to be compact-sized, thereby there is needed no large device for removing impurities from an entire water returning to the waste heat recovery boiler 20 and a cost reduction can be realized.

[0122] In the above, the invention has been described on the embodiments illustrated in the figures but the invention is not limited thereto but, needless to mention, may be added with various modifications in the concrete structures within the scope of the invention as claimed herebelow.

INDUSRIAL APPLICABILITY:

[0123] According to the first invention hereof, in a combined cycle power plant constructed of combination of a gas turbine plant and a steam turbine plant and comprising a waste heat recovery boiler for generating a steam turbine driving steam by use of gas turbine exhaust heat; steam supplied from an intermediate pressure evaporator is mixed into a cooling steam supply passage for supplying therethrough exhaust steam from a high pressure steam turbine as cooling steam into a high temperature portion of the gas turbine, thereby cooling steam temperature is lowered with the entire efficiency being by no means lowered and the gas turbine high temperature portion which is a portion to be cooled can be satisfied by a less heat resistant ability so as to be designed and made of a less expensive and easily obtainable material and yet a sufficient amount of the cooling steam is secured so as to ensure a stable cooling. Thus, a combined cycle power plant which is remarkably excellent in the cost saving aspect and the cooling performance aspect can be obtained.

[0124] According to the second invention hereof, in a combined cycle power plant constructed of combination of a gas turbine plant and a steam turbine plant and comprising a waste heat recovery boiler for generating a steam turbine driving steam by use of gas turbine exhaust heat; exhaust steam supplied from a high pres-

sure steam turbine and cooled by gas turbine fuel is supplied into a high temperature portion of the gas turbine as cooling steam, thereby the gas turbine high temperature portion which is a portion to be cooled can be satisfied by a less heat resistant ability so as to be designed and made of a less expensive and easily obtainable material and yet a sufficient amount of the cooling steam is secured so as to ensure a stable cooling. Thus, a combined cycle power plant which is remarkably excellent in the cost saving aspect and the cooling performance aspect can be obtained.

[0125] According to the third invention hereof, in a combined cycle power plant constructed of combination of a gas turbine plant and a steam turbine plant and comprising a waste heat recovery boiler for generating a steam turbine driving steam by use of gas turbine exhaust heat; steam which has cooled a gas turbine high temperature portion is led into a reheater for reheating thereof, thereby even if the cooling steam which has cooled the gas turbine high temperature portion is not given a sufficient heat, said cooling steam is reheated at the reheater to be given a sufficient heat securely and this heat so made up by the reheater is recovered at a downstream intermediate pressure turbine etc. and enhancement of the entire efficiency can be attained.

[0126] According to the fourth invention hereof, in a combined cycle power plant constructed of combination of a gas turbine plant and a steam turbine plant and comprising a waste heat recovery boiler for generating a steam turbine driving steam by use of gas turbine exhaust heat; a high pressure turbine by-pass passage is provided for connecting a superheated steam supply passage for supplying therethrough superheated steam from a high pressure superheater into a high pressure turbine and a cooling steam supply passage for supplying therethrough exhaust steam from the high pressure turbine as cooling steam into a gas turbine high temperature portion, and when the plant is to be started, the gas turbine is warmed up in advance by use of an auxiliary boiler or its own compressed air or the like and an initial steam generated at the own boiler is supplied into a cooling steam passage of the gas turbine via the high pressure turbine by-pass passage so that the warming-up is assisted and accelerated. Further, when the own boiler steam starts to be generated stably, said high pressure turbine by-pass passage is closed and a high pressure superheated steam is introduced into the high pressure turbine and cooling of the gas turbine is done by a high pressure exhaust steam from the high pressure turbine. Thus, said gas turbine cooling can be done stably with none of thermal shock etc. being caused, stability of operation is enhanced and a highly reliable plant can be obtained.

[0127] According to the fifth invention hereof, as a gas turbine cooling method in the combined cycle power plant of the first invention; the gas turbine is supplied with the cooling steam while the plant is operated such that when inlet temperature of the high pressure turbine is set to approximately 566°C, inlet pressure of the high pressure turbine is adjusted to 165 to 175 ata and exhaust steam of the high pressure turbine is maintained to temperature of 330 to 250°C and pressure of 35 to 30 ata, thus the cooling steam of approximately 566°C at the high pressure turbine inlet is adjusted to the pressure of 165 to 175 ata, thereby the property of the high pressure exhaust steam at the high pressure turbine outlet is lowered to 330 to 250°C and 35 to 30 ata and the cooling steam temperature also can be lowered without lowering of the efficiency of the downstream equipments, the intermediate pressure turbine for example. Hence, the downstream gas turbine high temperature portion which is a portion to be cooled can be satisfied by a less heat resistant ability so as to be made of a less expensive and easily obtainable material and yet a stable cooling can be done without lowering of the entire efficiency. Thus, a combined cycle power plant which is remarkably excellent in the cost saving aspect and the cooling performance aspect can be obtained.

[0128] According to the sixth invention hereof, as a gas turbine cooling method in the combined cycle power plant mentioned in any one of the first to fourth inventions; the gas turbine high temperature portion is supplied into with auxiliary steam prior to start of the gas turbine so that the gas turbine is warmed up, the auxiliary steam being of pressure of combustion gas pressure or more of starting time of the gas turbine; the gas turbine is then started in that state to do a holding operation for a predetermined time at a predetermined load; when steam from the waste heat recovery boiler comes to a condition of the auxiliary steam, supply of the auxiliary steam is stopped and steam coming, by-passing the high pressure turbine, from the high pressure superheater of the waste heat recovery boiler is supplied into the gas turbine high temperature portion; and when output of the waste heat recovery boiler comes to a rating thereof, the by-passing is closed and exhaust steam from the high pressure turbine is supplied into the gas turbine high temperature portion so as to switch to a rated operation. The cooling steam is so supplied with said procedures being taken, thereby a safe and stable starting of the plant takes place without occurrence of thermal shock which is unfavorable to the cooled portion to be then switched to a stable rated operation, thus reliability of this kind of the combined cycle power plant can be further enhanced.

[0129] According to the seventh invention hereof, as a gas turbine cooling method in the combined cycle power plant mentioned in any one of the first to fourth inventions; while the gas turbine high temperature portion is closed upstream and downstream thereof, the gas turbine is started to do a holding operation for a predetermined time at a low load of level which needs no cooling of the gas turbine high temperature portion; when the waste heat recovery boiler comes to a level to

generate a predetermined own boiler steam, the closing is opened and steam coming, by-passing the high pressure turbine, from the high pressure superheater of the waste heat recovery boiler is supplied into the gas turbine high temperature portion; and when output of the waste heat recovery boiler comes to a rating thereof, the by-passing is closed and exhaust steam from the high pressure turbine is supplied into the gas turbine high temperature portion so as to switch to a rated operation. The cooling steam is so supplied with said procedures being taken, thereby the gas turbine high temperature portion is heated and cooled gradually in a good balance between the temperature elevation and the cooling and a safe and stable stating of the plant takes place without occurrence of thermal shock which is unfavorable to the cooled portion to be then switched to a stable rated operation, thus reliability of this kind of the combined cycle power plant can be further enhanced.

[0130] According to the eighth invention hereof, in the combined cycle power plant mentioned in any one of the first to fourth inventions; a dust collecting filter is provided at a cooling steam inlet portion of the gas turbine high temperature portion and a mesh of the dust collecting filter is in a range of 100 to 1000 μm, thereby dropped solids such as scales etc. in the main steam system are prevented from coming into the cooling steam passage, frequency of clogging of the dust collecting filter due to fine particles is lessened so that a long hour use thereof becomes possible and frequent exchange work of same is reduced. Also, no large facilities are needed for dust collection of the steam flowing into the gas turbine cooling steam passage and a simple structure of the dust collecting filter is realized by use of a detachable mesh portion.

[0131] Finally, according to the ninth invention, in the combined cycle power plant mentioned in any one of the first to fourth inventions; there are provided an impurity removing device which is exclusive for treating water for temperature adjustment, an economizer which is exclusive for heating the water from said impurity removing device and a spray nozzle for spraying the water heated at said economizer into cooling steam which flows into the gas turbine high temperature portion, so that said cooling steam is adjusted of its temperature. Thus, only by providing the exclusive impurity removing device of the capacity only to treat the water of the amount necessary for adjusting the cooling steam temperature and the exclusive economizer for heating only the water so treated at the impurity removing device, there are needed no large facilities such as an impurity removing device for treating entire amount of the water condensed, etc. and cost reduction of the facilities can be achieved. Moreover, the water to be sprayed is heated to become a high temperature water of a temperature near the cooling steam temperature, hence the adjustment of the cooling steam temperature becomes facilitated and can be done efficiently.

Claims

1. A combined cycle power plant comprising combination of a gas turbine plant, a waste heat recovery boiler and a steam turbine plant;

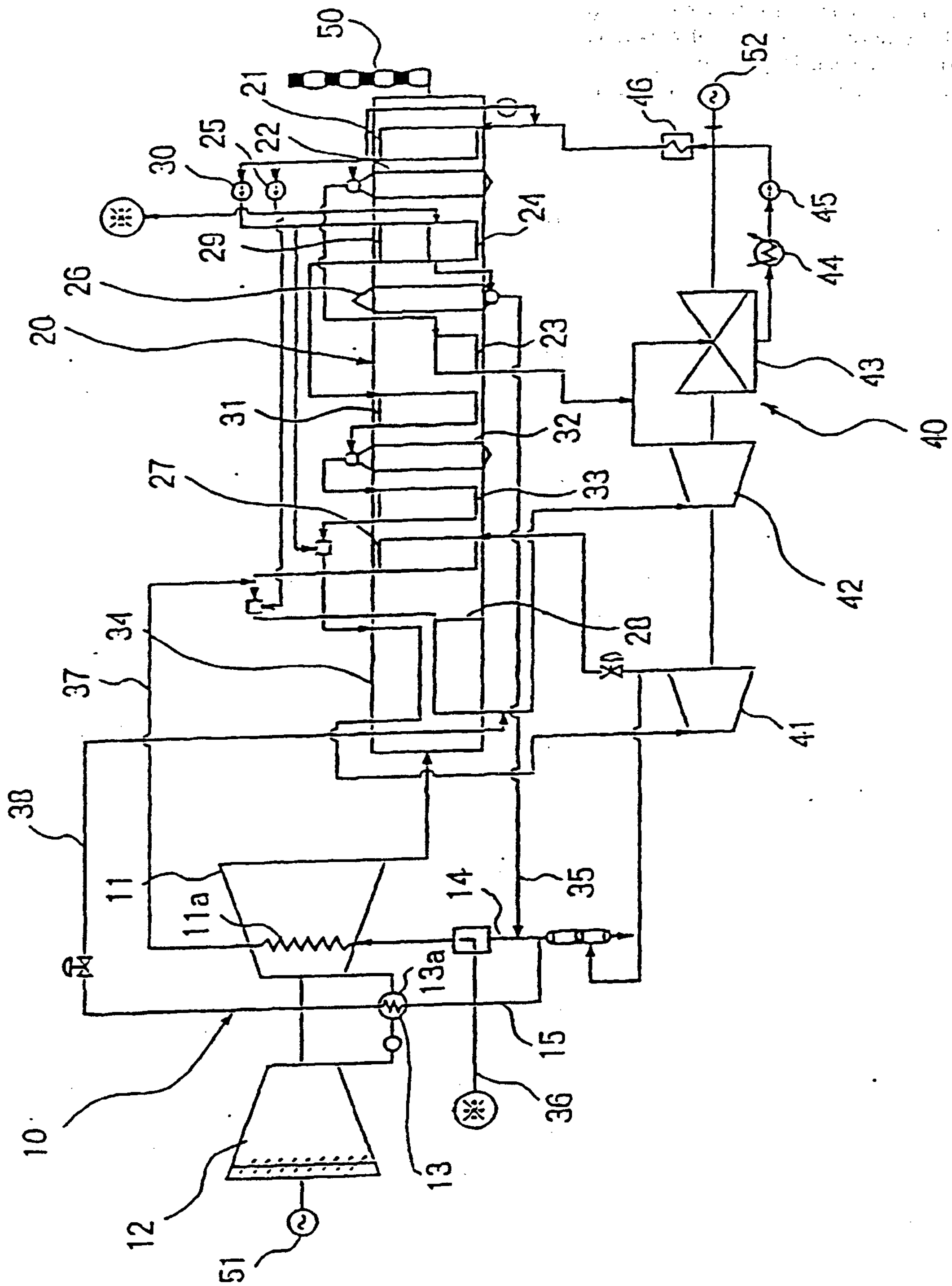
   said gas turbine plant being constructed of a gas turbine, an air compressor driven by said gas turbine and a combustor for burning fuel together with compressed air supplied from said air compressor;
   said waste heat recovery boiler being for generating steam by exhaust heat of said gas turbine as heat source and being constructed of portions, mutually connected by pipings, of a high pressure steam generating portion, an intermediate pressure steam generating portion and a low pressure steam generating portion; said high pressure steam generating portion comprising a high pressure economizer, a high pressure feed water pump, a high pressure evaporator and a high pressure superheater; said intermediate pressure steam generating portion comprising an intermediate pressure economizer, an intermediate pressure feed water pump, an intermediate pressure evaporator and an intermediate pressure reheater; and said low pressure steam generating portion comprising a low pressure economizer, a low pressure feed water pump, a low pressure evaporator and a low pressure superheater; and
   said steam turbine plant being constructed of steam turbines, mutually connected by pipings, of a high pressure turbine, an intermediate pressure turbine and a low pressure turbine; said high pressure turbine being supplied with high pressure steam from said high pressure steam generating portion; said intermediate pressure turbine being supplied with intermediate pressure steam from said intermediate pressure steam generating portion; and said low pressure turbine being supplied with low pressure steam from said low pressure steam generating portion;
   characterized in that steam supplied from said intermediate pressure evaporator (26) is mixed into a cooling steam supply passage (14) for supplying therethrough exhaust steam from said high pressure turbine (41) as cooling steam into a high temperature portion (11a, 13a) to be cooled of said gas turbine (11).

2. A combined cycle power plant comprising combination of a gas turbine plant, a waste heat recovery boiler and a steam turbine plant;

   said gas turbine plant being constructed of a

one of Claims 1 to 4, characterized in that there are provided an impurity removing device (60) which is exclusive for treating water for temperature adjustment, an economizer (70) which is exclusive for heating the water from said impurity removing device (60) and a spray nozzle (72) for spraying the water heated at said economizer (70) into cooling steam which flows into the high temperature portion (11a, 13a) to be cooled of said gas turbine (11), so that said cooling steam is adjusted of its temperature.

Fig. 1


10
11
11a
12
13
13a
14
15
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22
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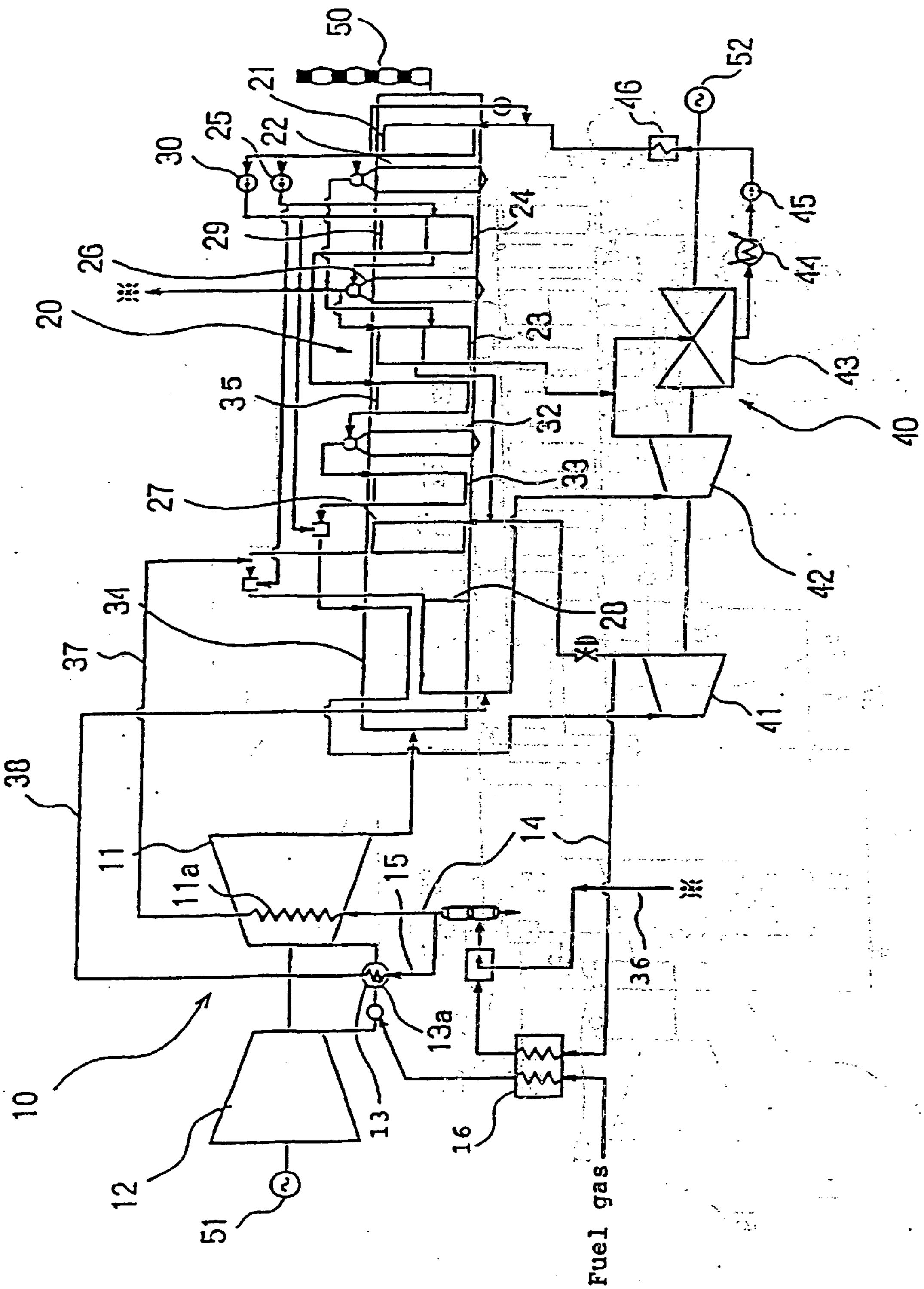
Fig. 2


10
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11a
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13a
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16
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42
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44
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46
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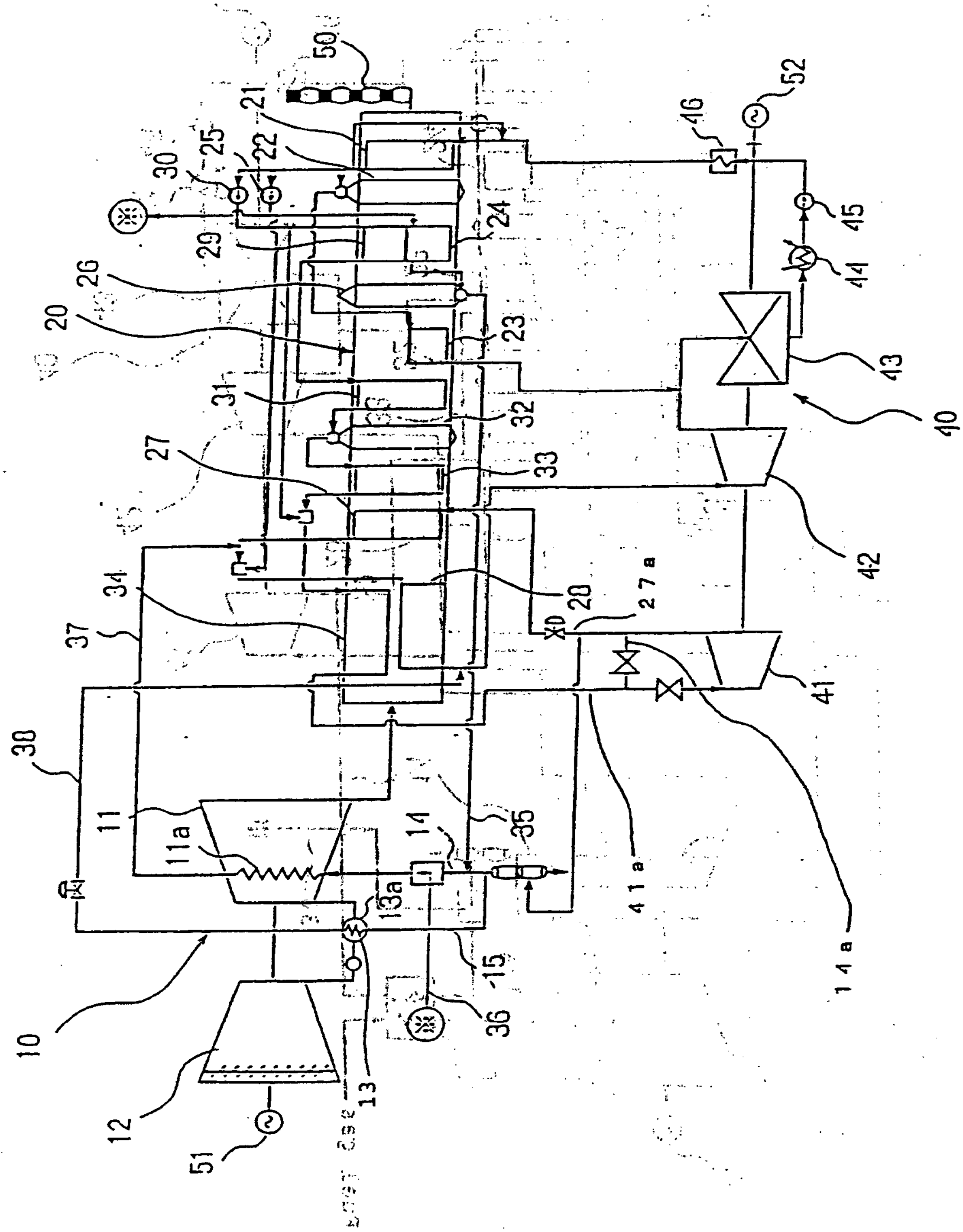
Fuel gas
※
※

Fig. 3


10
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11a
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13
13a
14
14a
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20
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27a
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41a
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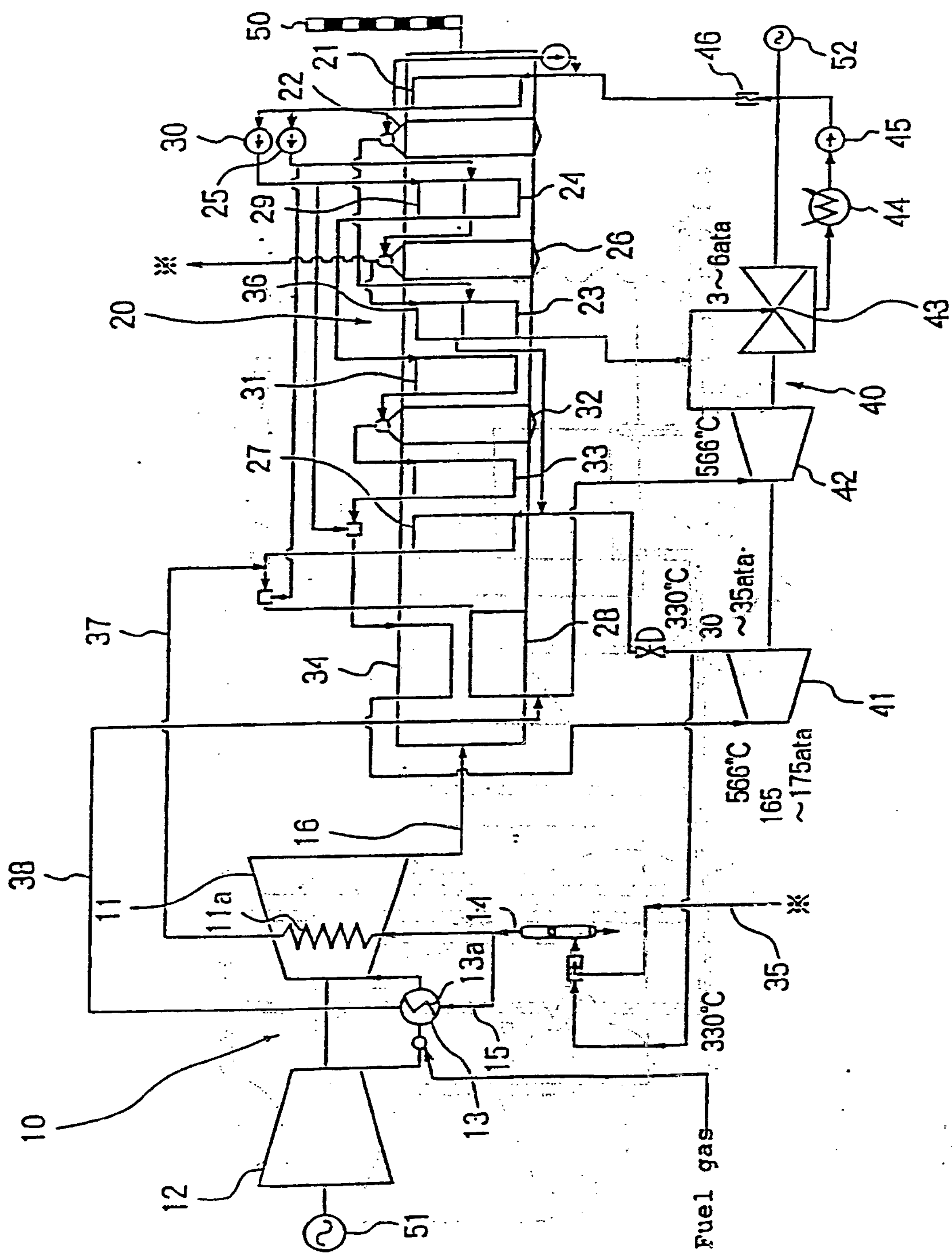
Fig. 4



10
11
11a
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13
13a
14
15
16
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28
29
30
31
32
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34
35
36
37
38
40
41
42
43
44
45
46
50
51
52
566°C
165
~175ata
330°C
30
~35ata
566°C
3~6ata
330°C
※
※
Fuel gas

Fig. 5

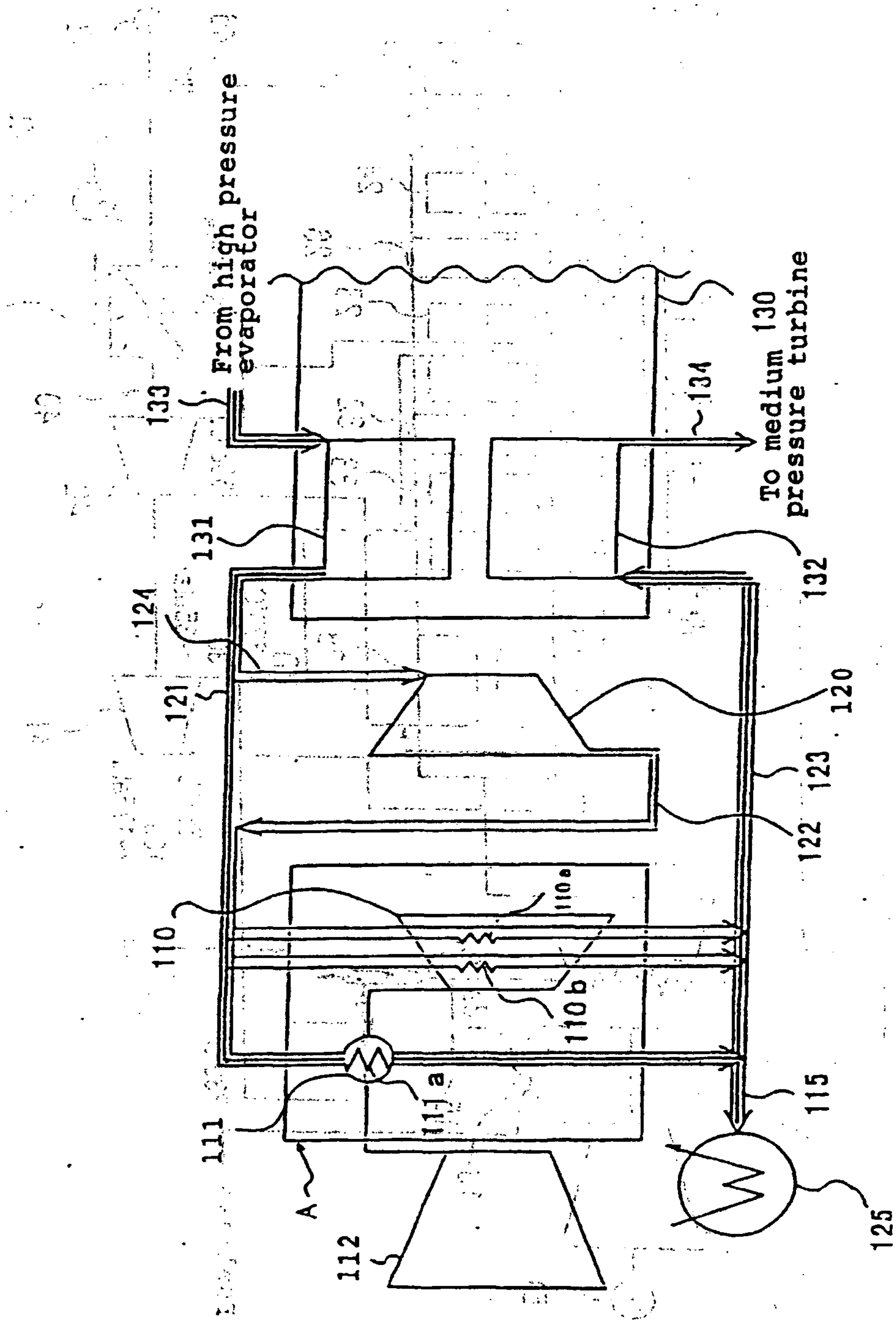
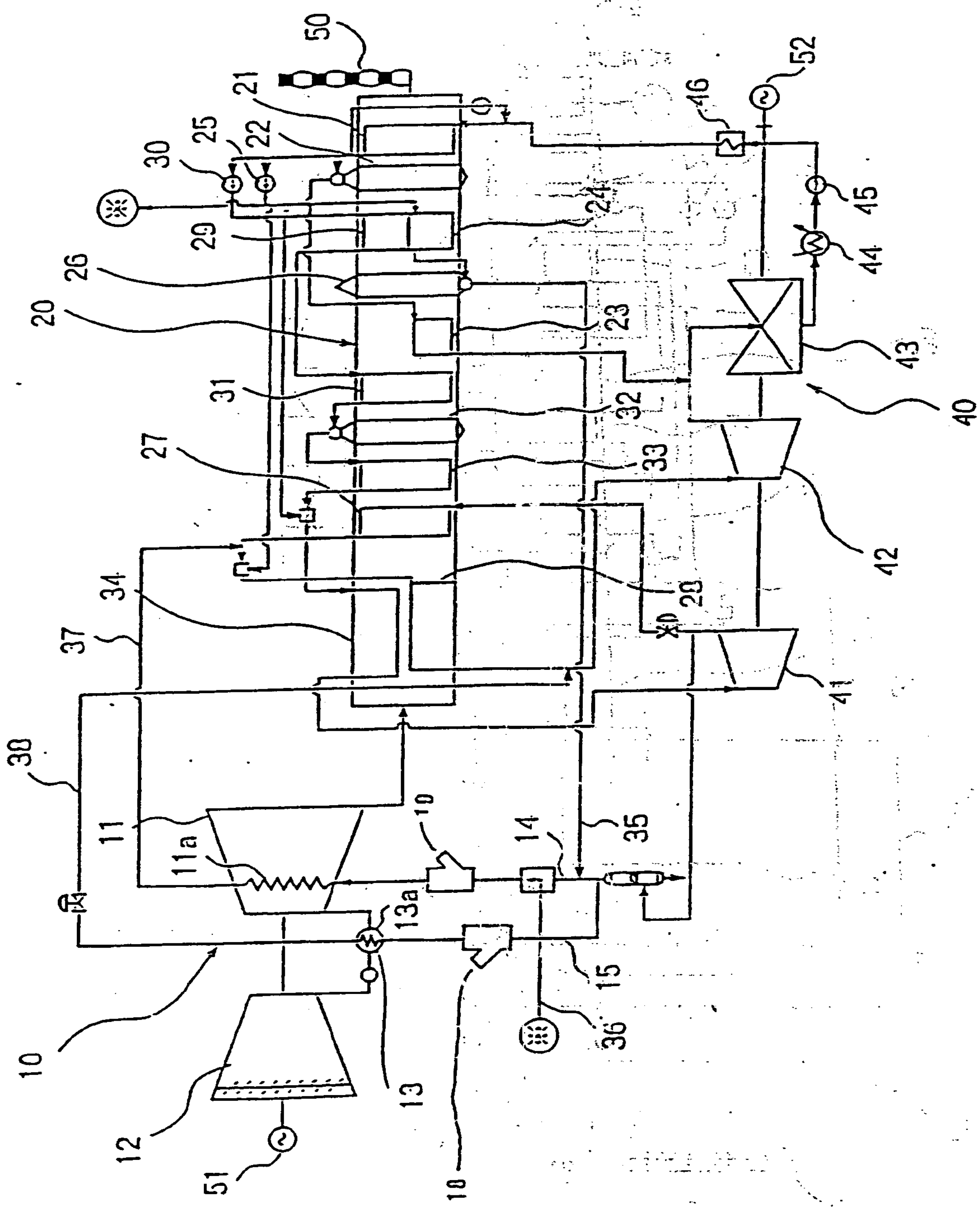

From high pressure evaporator
To medium pressure turbine
130
133
134
131
132
124
121
120
123
122
110
110a
110b
111
111a
115
125
A
112

Fig. 6


10
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11a
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13a
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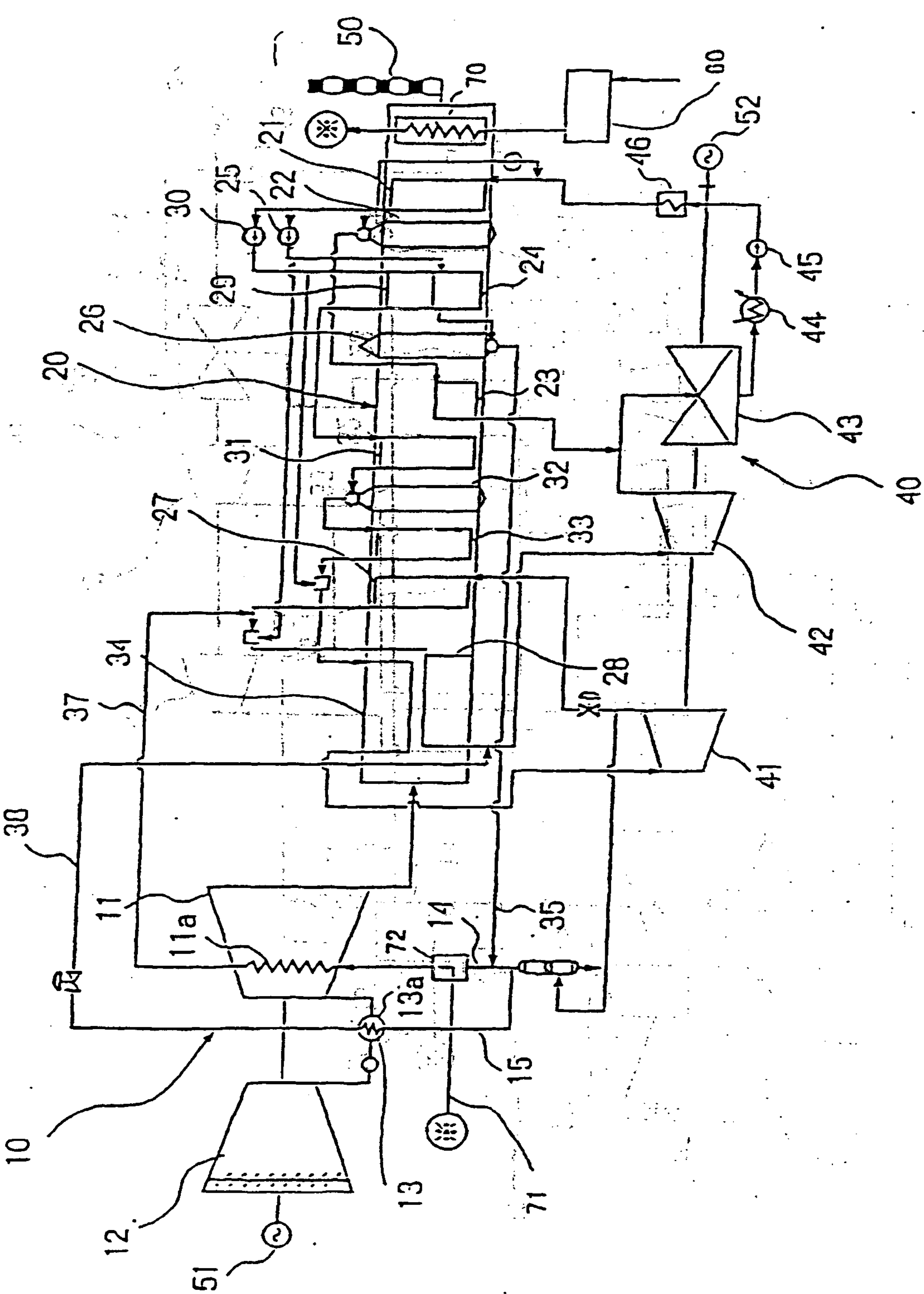
Fig. 7


10
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11a
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13a
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72
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/01727

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^6 F02C6/18, 7/18, F01K23/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl^6 F02C6/18, 7/16, 7/18, F01K23/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926-1996	Jitsuyo Shinan Toroku Koho	1996-1998
Kokai Jitsuyo Shinan Koho	1971-1998	Toroku Jitsuyo Shinan Koho	1994-1998

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP, 0743425, A1 (General Electric Co.), November 20, 1996 (20. 11. 96), Fig. 1A to Fig. 2 & JP, 09-112292, A	1-9
Y	JP, 06-323162, A (Hitachi, Ltd.), November 22, 1996 (22. 11. 96), Figs. 6, 7 (Family: none)	1, 9
Y	JP, 07-004210, A (Hitachi, Ltd.), January 10, 1995 (10. 01. 95), Fig. 1 (Family: none)	3, 5, 9
Y	JP, 09-088519, A (Toshiba Corp.), March 31, 1997 (31. 03. 97), Figs. 1, 4 (Family: none)	6
Y	JP, 06-093879, A (Hitachi, Ltd.), April 5, 1994 (05. 04. 94), Figs. 1 to 12 (Family: none)	7

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search July 10, 1998 (10. 07. 98)	Date of mailing of the international search report July 21, 1998 (21. 07. 98)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/01727

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 07-119413, A (Hitachi, Ltd.), May 9, 1995 (09. 05. 95), Figs. 1 to 3 (Family: none)	9
EX	JP, 10-077806, A (Toshiba Corp.), March 24, 1998 (24. 03. 98), Figs. 1, 5, 6, 9, 10 (Family: none)	1
EY	JP, 10-131719, A (Mitsubishi Heavy Industries, Ltd.), May 19, 1998 (19. 05. 98), Fig. 1 (Family: none)	2
EY	JP, 09-256815, A (Toshiba Corp.), September 30, 1997 (30. 09. 97), Fig. 5 (Family: none)	4
A	JP, 05-163960, A (Tohoku Electric Power Co., Inc.), June 29, 1993 (29. 06. 93), Figs. 1 to 9 (Family: none)	1-9

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